

Development of far-UV-sensitive silicon imaging arrays for compact UV instrumentation

Completed Technology Project (2018 - 2021)



Project Introduction

Recent advances in the UV responsivity of silicon-based imaging arrays motivate us to develop and test a fully UV-optimized CMOS-detector focal-plane array (FPA) prototype. Notable innovations in silicon-based FPAs have led to the development of detectors with quantum efficiencies at mid-UV wavelengths (200-300 nm) that are competitive with state of the art microchannel plate (MCP) technology (e.g., Bai et al., SPIE, 2008; Nikzad et al., 2011) with the added advantage that, unlike MCPs, they do not require high-voltage power supplies. Hence, the utilization of these innovative detectors in future UV spectrographs or imagers will reduce the power, mass and complexity of such instruments over their current equivalents, making them well-suited for future low-cost planetary missions including those based on CubeSats and other SmallSat platforms. In previous studies we characterized the far-UV (100-200 nm) performance of UV-optimized n-type silicon devices at SwRI (Davis et al, SPIE 2012) and began to develop methods of enhancing the far-UV response by doping thinned-silicon wafers with antimony using Molecular Beam Epitaxy (MBE) (Retherford et al., JATIS, 2015). This work demonstrated that the MBE process is feasible for silicon wafers with thicknesses as little as 100 microns; an important result, given the short absorption depth of far-UV photons in silicon. Methods of cleaning the wafers prior to MBE were investigated at MIT Lincoln Laboratory, and the MBE process was optimized through a series of experiments in which the target doping concentrations, growth temperatures and epitaxial-silicon thicknesses were varied. Exploiting this initial success, we intend to (1) complete the optimization of the MBE process for n-type backside-illuminated CMOS hybrid arrays from Teledyne, (2) expand the assessment to include MBE process on state-of-the-art p-type CMOS monolithic arrays made using ~10-micron epitaxial-wafers from Teledyne e2v, and investigate options for anti-reflectance coatings to reject longer wavelength light, and (3) fabricate and test UV-optimized photodiodes, analyzing their response to wavelengths from far UV to the visible. We will also develop a full prototype FUV-optimized CMOS FPA taking advantage of flight-heritage array formats such as HAWAII-1RG. For the component technologies developed in this program, the entrance TRL of 3 will be raised to TRL 4 or higher upon exiting the program. Once developed, these UV-optimized devices will enable highly capable SmallSat investigations of lunar polar volatiles, Venusian upper atmosphere composition and dynamics, water vapor plumes at Enceladus and/or Europa, and other targeted science measurements detailed within the Vision and Voyages Planetary Decadal Survey.

Anticipated Benefits

Our development of UV-sensitive CMOS detectors will facilitate more compact UV instrumentation. This is potentially beneficial to any future NASA missions with the goal of characterizing planetary surfaces and atmospheres, but is particularly important for small satellite and CubeSat missions, which lack the



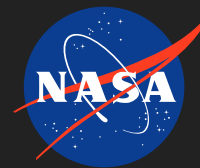
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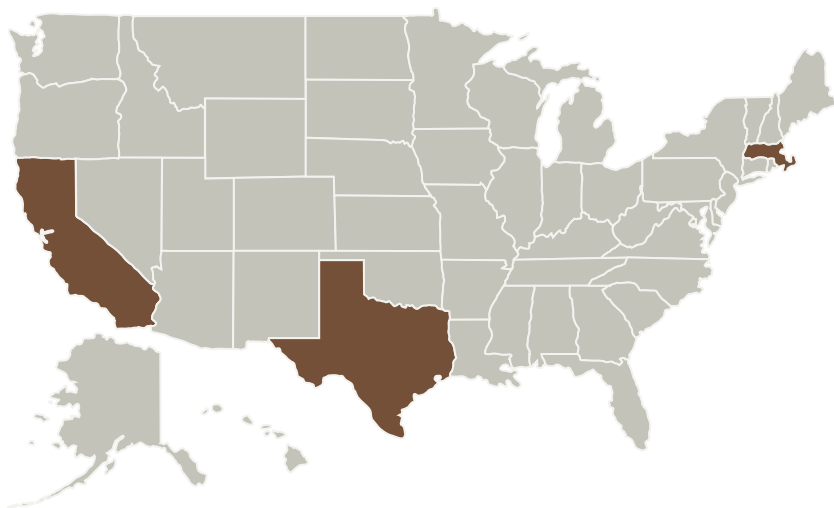
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resources to carry typical microchannel plate-based UV instruments.

Primary U.S. Work Locations and Key Partners



Organizations Performing Work	Role	Type	Location
Southwest Research Institute - San Antonio (SWRI)	Lead Organization	Academia	San Antonio, Texas
Teledyne Scientific and Imaging	Supporting Organization	Industry	

Primary U.S. Work Locations	
California	Massachusetts
Texas	

Organizational Responsibility

Responsible Mission Directorate:

Science Mission Directorate (SMD)

Lead Organization:

Southwest Research Institute - San Antonio (SWRI)

Responsible Program:

Planetary Instrument Concepts for the Advancement of Solar System Observations

Project Management

Program Director:

Carolyn R Mercer

Program Manager:

Haris Riris

Principal Investigator:

Philippa M Molyneux

Co-Investigators:

Ronald B Kalmbach
Ujjwal Raut
Kurt D Retherford
James W Beletic
James A Gregory
Michael W Davis
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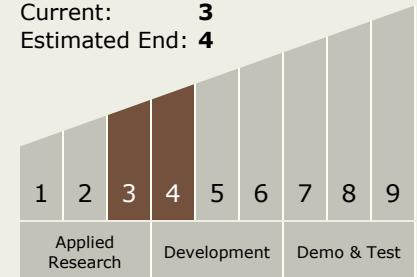
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Technology Maturity (TRL)

Start: **3**
Current: **3**
Estimated End: **4**



Technology Areas

Primary:

- TX08 Sensors and Instruments
 - └ TX08.1 Remote Sensing Instruments/Sensors
 - └ TX08.1.1 Detectors and Focal Planes

Target Destination

Others Inside the Solar System